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Owens et al.

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[54] **LIGHT-DEFLECTING SYSTEM FOR EFFECTING BRAGG DIFFRACTION OVER A WIDE BANDWIDTH**

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[52] **U.S. Cl.** **350/161**
[51] **Int. Cl.** **G02f 1/32**
[58] **Field of Search** 350/161

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[57] **ABSTRACT**

A system is described in which a laser beam is diffracted or deflected into at least 1,500 resolvable positions. The system includes an acoustooptic device comprising a block of acoustooptic material, such as lead molybdate, with an array of piezoelectric transducers bonded to one side or surface. In order to acheive operation over a wide bandwidth, it is necessary to steer the direction of propagation of the acoustic wave so that the Bragg diffraction condition is approximately satisfied. This can be accomplished by providing an array of steps which is cut into an edge surface of the acoustooptic block, each step being of a particular width and height which are related to the wavelength of the acoustic wave at the designed frequency of the device. A transducer is bonded to each step, the transducers being serially connected to an oscillator means which generates a series of electrical signals within a predetermined frequency range for causing sound waves to be radiated or propagated by each transducer. Since the transducers are serially connected, they are oppositely poled and radiate in phase. Hence the electrical field direction alternates.

4 Claims, 6 Drawing Figures

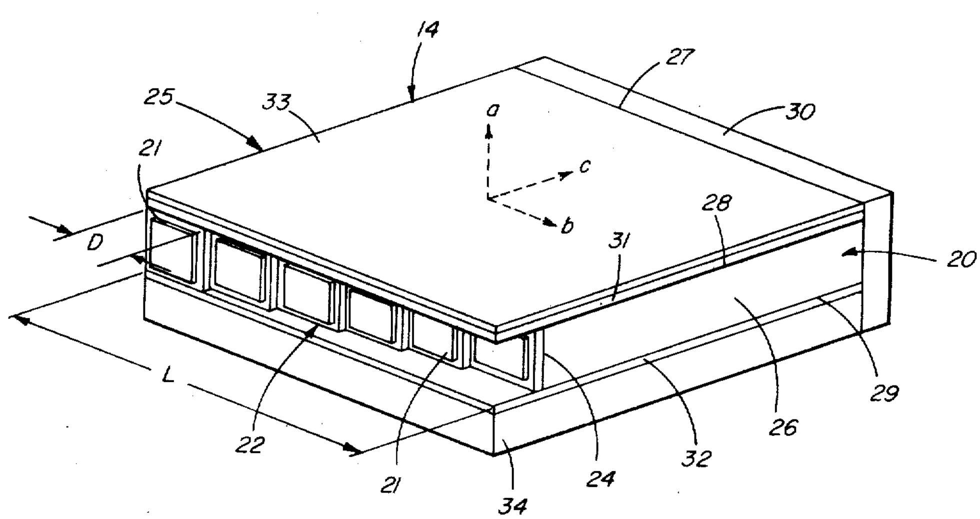
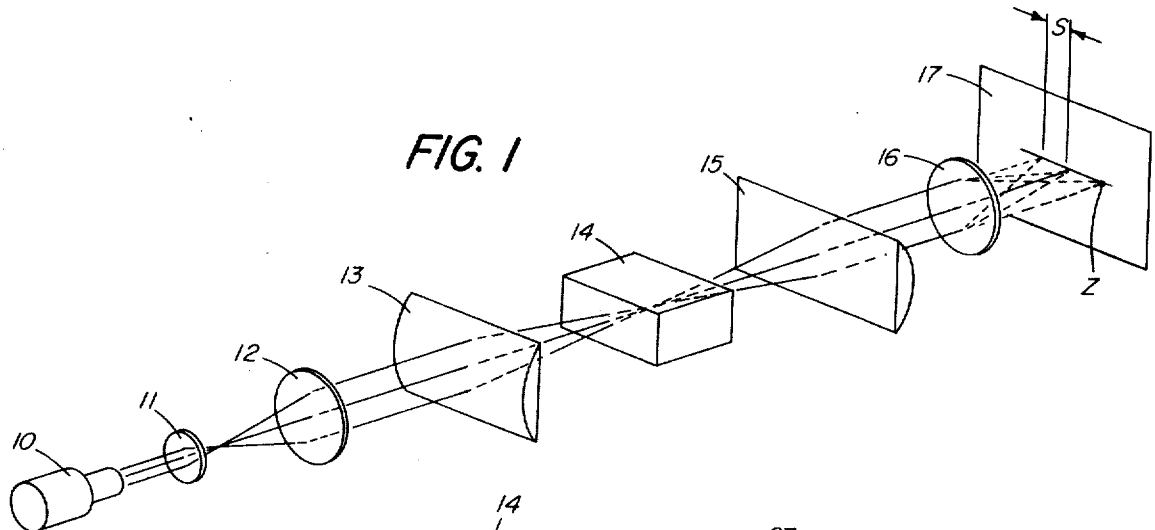


FIG. 1



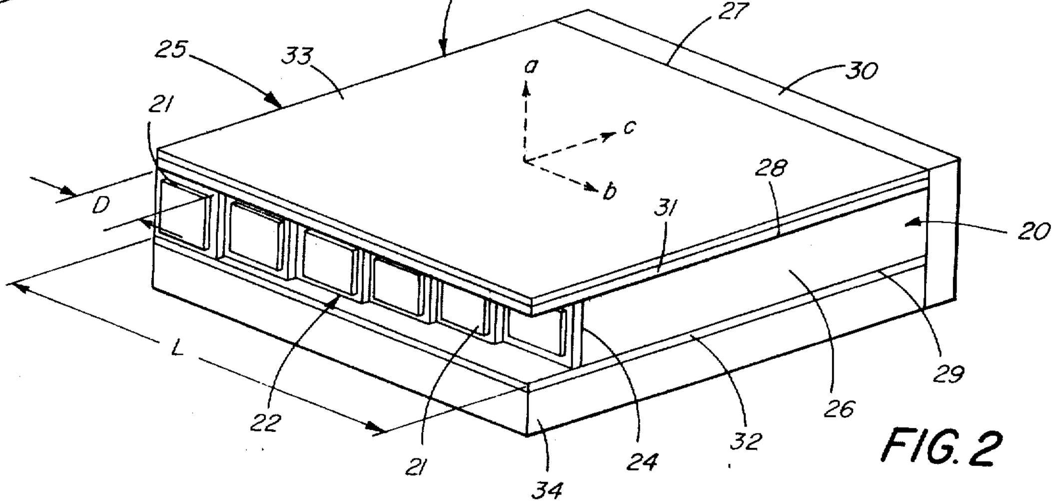


FIG. 2

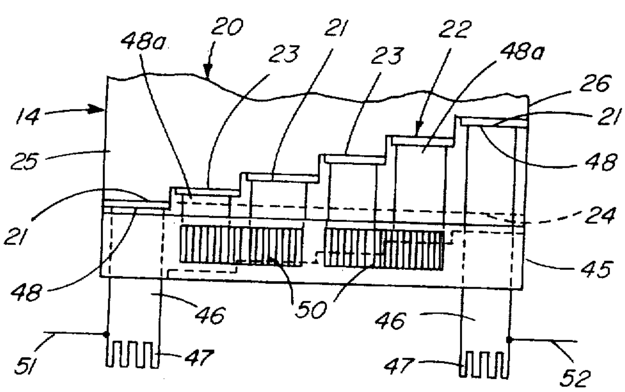


FIG. 6

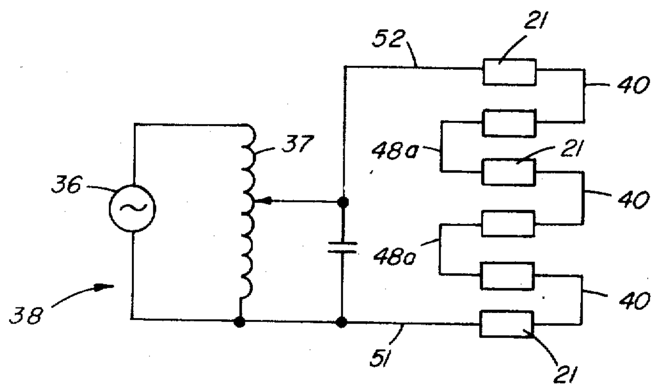


FIG. 3

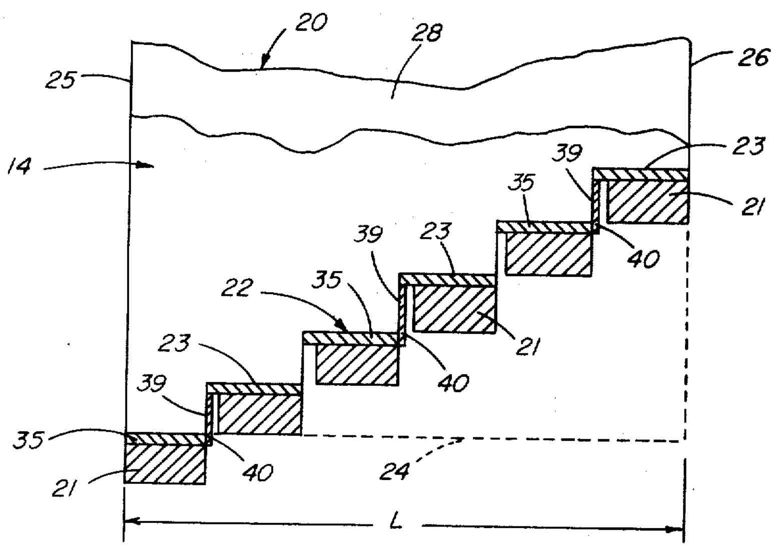


FIG. 4

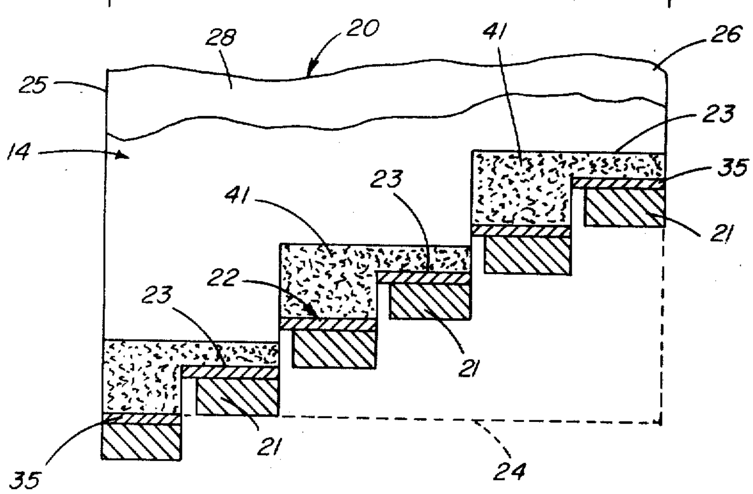


FIG. 5

A LIGHT-DEFLECTING SYSTEM FOR EFFECTING BRAGG DIFFRACTION OVER A WIDE BANDWIDTH

FIELD OF THE INVENTION

The present invention relates to an acoustooptic light-deflecting system and, more particularly, to such a system in which light and acoustic waves interact to diffract a beam of light into a plurality of positions which can be used for recording or for scanning in a continuously operative system.

DESCRIPTION OF THE PRIOR ART

The prior art discloses a number of different types of elements that can be used as light diffractors or deflectors, and these are based on a number of different physical principles. The performance of these devices is normally determined or specified by the number of resolvable spots or beam positions (the total scan angle divided by the diffraction angle of the output beam), the access time (the time required to position or move the spot or beam into the next or a specified position), and the optical efficiency (the ratio of optical power in the spot at the beam position to the power of the input beam). Such diffractors or deflectors can be of a mechanical type, such as multi-faceted mirrors which are mounted for rotation at a relatively high speed, as well as galvanometer mirrors. While these deflectors can move a light beam into a large number of positions within a relatively short time, their reliability is considered to be inadequate for a practical high-resolution system. While rotatable mirrors will provide a fast scan time, they are quite expensive to incorporate in a system. On the other hand, galvanometers are relatively inexpensive but have a scan time that is too slow for most applications.

While there are many types of nonmechanical deflectors, these are, for the most part, of such limited capacity in terms of resolvable spots, that they are totally inadequate for a high-resolution system. For a high-resolution display (500 spots or more), acoustooptic diffractors or deflectors offer the simplest approach to achieving high resolution with reasonably short scan times. However, prior devices of the acoustooptic type have certain disadvantages in that, if they are capable of producing a large enough number of resolvable spots or beams the access time is then too long to be of value in a high-speed image-recording and display system. For example, a high-resolution device has been made which will generate about **1600** beam positions but requires 64μ sec. access time. Another disadvantage of known devices is that, if the access time can be attained, then the devices are incapable of generating a large enough number of spots or beam positions to provide the desired resolution. A commerically available device which has a 10.6 μ sec. access time will generate only about 775 spots. In addition, such commercial systems do not provide reasonably constant diffraction efficiency throughout the full scan, nor do they make use of an optimum resolution-efficiency trade-off in design.

As is well known, light waves can be diffracted by sound waves, as a result of which the light waves are deflected at a particular angle or angles depending on the frequency characteristics of the sound waves. In accordance with the particular application, the sound waves can be modulated either in amplitude or frequency. When the sound wavefronts are projected across the

light wavefronts so that the angle between is in accordance with the relationship of Bragg, the traveling sound waves act as if they were traveling mirrors. Consequently, for a given frequency relationship, the angles of incidence and diffraction of the light are the same as in the case of an ordinary mirror. With planar sound and light wavefronts and without adjustment of the relative beam positions to maintain the Bragg relationship, the usable Bragg angle reflection obtainable is over only a limited range of sound frequency. It is also recognized by the prior art that in terms of resolution available with certain apparatus, limitations are to be found with respect to scanning speeds, practical ranges of needed sound frequencies and the maximum useful lightbeam aperture width.

SUMMARY OF THE INVENTION

One object of this invention is to provide a light- deflecting system which will provide a large number of resolvable spots with a relatively short access time.

Another object of the invention is to provide a light-deflection system having improved ranges of diffraction or deflection and improved response time which can be utilized for scanning over a substantial frequency range without loss in efficiency.

Still another object of the invention is to provide a light-deflecting system which utilizes a relatively simple acoustooptic element associated with requisite circuitry for operation at much higher speeds and which is capable of producing a larger angle through which a light beam can be deflected.

A still further object of the invention is to provide a signal-modulating system in which an acoustooptic device and an illumination system are incorporated to provide a large number of resolvable spots or beam positions, a system having a short access time, and a high diffraction efficiency, the light beam being controlled as to size, position and angle of incidence on the acoustooptic element.

These and other objects and the advantages of the invention will be apparent to those skilled in the art by the description set forth hereinbelow.

The above-mentioned objects of the invention can be obtained by a system in which a laser beam is diffracted or deflected into at least 1,500 resolvable spots or beam positions, and which gives a diffraction efficiency of at least 10% over the full bandwidth. The time-bandwidth product is 1,665 but if used with a 10% retrace time in a linear scanning mode, the effective resolution is then reduced to 1,500 positions. In addition, the device operates at a low power density and can also be operated at a high power level to achieve larger diffraction efficiency.

The need for a device of this type becomes apparent when one attempts to use the devices disclosed in the prior art for a high-resolution image-recording and/or display system. As mentioned hereinabove, commercial devices will give about 775 resolvable beam positions or less with a retrace time of 10 μ sec. or more. On the other hand, for a number of beam positions approaching 1,600, a retrace time of 64 μ sec. is required. Neither of these would be acceptable in that performance specifications for a system as described hereinbefore requires at least 1,500 beam positions and a retrace time of 14 μ sec. or less.

The acoustooptic device utilized in the present system comprises a block of acoustooptic material, such as lead molybdate, with an array of piezoelectric transducers bonded to one side or surface. The acoustic waves launched by the transducers gives rise to a variation of refractive index across the aperture and this wave diffracts part of the illuminating light through an angle $\theta \cong \lambda f/v$, where λ is the vacuum wavelength of the illuminating light, f is the frequency of the acoustic wave, and v is the acoustic wave velocity. In order to achieve operation over a wide bandwidth, it is necessary to steer the direction of propagation of the acoustic wave so that the Bragg diffraction condition is approximately satisfied. This can be accomplished by providing an array or series of steps which is cut into an edge surface of the acoustooptic block, each step being of a particular width and height and related to the wavelength of the acoustic wave at the designed frequency. As discussed in more detail hereinbelow, it will be evident to those skilled in the art that the particular acoustooptic element and the relation of the plurality of transducers provides a device capable of obtaining the specific performance characterics required for a high-resolution system.

As used herein, the terms "light" and "sound" are considered to be most general. That is, "light" is meant to include ordinarily visible electromagnetic waves, as well as electromagnetic radiation, at wavelengths above or below the visible portion of the spectrum. The term "sound" (and "acoustic") refers to propagating physical or mechanical wave energy and is meant to include not only that in the audible range but through the radio-microwave frequency range as well. By "access time" is meant the time required for a sound wave being propagated at a particular frequency to be effective through the full extent of the acoustooptic material. On the other hand, "scan time" refers to the time required for the light beam to scan one complete line in a linear scan mode. "Flyback time" refers to the time required for the beam to return to its initial position from the end of the previous line and can be equivalent to access time.

DESCRIPTION OF THE DRAWINGS

Reference is now made to the accompanying drawings wherein like reference numerals and characters designate like parts and wherein:

FIG. **1** is a schematic perspective view showing an optical system in which a light-deflecting element is used for recording information or for displaying information in an information receiving plane;

FIG. **2** is a perspective view of a preferred embodiment of an acoustooptic element in accordance with the invention;

FIG. **3** is a schematic wiring diagram showing the manner in which the transducer members on the acoustooptic element are serially connected so as to be opposite in polarity;

FIGS. **4** and **5** are enlarged partial plan views of an acoustooptic element having a step array of surfaces and the manner in which the transducer members are bonded to respective surfaces of the acoustooptic element and interconnected so as to be in opposed polarity, as shown in FIG. **3**; and

FIG. **6** is a partial plan view of the acoustooptic element disclosed in FIG. **2** and showing the manner in which heat sinks can be interconnected to the transducer members.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With respect to FIG. **1**, a typical system for onedimensional scanning is show. In this system, a laser **10** provides a source of monochromatic light. Spherical lenses **11** and **12** expand and collimate the beam of light emanating from the laser **10.** A cylindrical lens **13** focuses the beam to a line at the center of the deflector, generally designated by the numeral **14.** Consequently, the full aperture width of deflector **14** is used but only a narrow height is required, thereby obtaining increased diffraction efficiency for a given transducer drive power. A second cylindrical lens **15** is used to regenerate a collimated beam of light from the beam emanating from the deflector **14.** This beam of light is then focused by a lens **16** onto an image-or information-receiving plane designated by the numeral **17.** In the plane **17**, S designates the range of the beam positions or the extent of the scan as the frequency is changed over the full frequency range. On the other hand, Z designates the position of the zero-order, undiffracted light in this same plane. Such a system can be used as one for recording or one for display; in the first case, a light-sensitive medium, such as a photographic or xerographic material can be positioned in plane **17** and moved by suitable means in X and/or Y directions and in synchronism with the scanning movement of the deflected beam to affect a recording system; and in the second case, suitable visual display means can be provided in plane **17,** such as a TV screen, a reproduction screen, etc. In the latter case, again depending on the use, additional elements and/or circuitry may be needed to provide a complete system. The optical system disclosed hereinabove is insensitive to aberrations in the cylindrical lenses. Other optical systems which can be shorter in length can comprise a different arrangement of lenses, prisms and/or mirrors to produce the same result. A more detailed description of the deflector per se will be given hereinbelow.

The deflector **14** consists of a rectilinear block **20** of acoustooptic material with a piezoelectric transducer member **21** bonded to each step **23** of an array **22** formed on an end surface **24** of block **20.** The acoustic wave launched by each of the transducer members **21** gives rise to a variation of the refractive index of the block **20** across the aperture in accordance with the number of steps **23.** Each of these waves diffracts part of the illuminating light through an angle $\theta \cong \lambda f/v$, where λ is the vacuum wavelength of the illuminating light, f is the frequency of the acoustic wave, and v is the acoustic wave velocity. In order to achieve operation over a large bandwidth or frequency range, it is necessary to steer the direction of propagation of the acoustic waves so that the Bragg diffraction condition is approximately satisfied. One of the methods of accomplishing this is shown in FIG. **2** and in more detail in FIGS. **4** and **5.**

It will be noted with respect to FIGS. **2, 4** and **5** that the array **22** of steps **23** is cut into the acoustooptic block **20.** Each of steps **23** has a width D and a height $P\Lambda/2$, wherein P is an integer greater than **0** and Λ is the wavelength of the acoustic wave at the design frequency f_A. At frequencies greater or less than f_A, each of transducer members **21** radiates a wave propagating perpendicular to the transducer surface but the composite wavefront is stepped and is effectively a single wave propagating at an angle. If the ratio of width D to height is correct the angle of propagation matches the Bragg requirements approximately and operation over an extended bandwidth or frequency range is possible. More important, proper array design permits operation over some specified frequency range with a greater total array length L than would otherwise be possible.

The diffraction efficiency is given by

$$\nu = \sin^2 \{ \pi^2/2\lambda^2 \, M_2 L^2 P_d \, [\sin(\pi x)/\pi x]^2 \, [\sin(\pi y)/N\sin(\pi y/N)]^2 \}^{1/2}$$

where

$$x = fl \, [\lambda/2nv^2 \, (f_A - f) + 0.443 \; 1/Lf_A \,]$$

and

$$y = fL \, [\lambda/2nv^2 \, (f_A - f) + 0.443 \; 1/Lf_A + P/2D \, (f - f_A)/ff_A]$$

In the above expressions ν is the ratio of optical power in the diffracted beam to incident power; M_2 is the figure of merit of the acoustooptic material, $n^6p^2/\rho v^3$, where ρ is the material density; L is the total length of the array; P_d is the effective acoustic power density in the deflecting medium; T is the width of each transducer which is normally slightly less than the step width; n is the refractive index of the acoustooptic medium; v is the acoustic wave velocity, D is the step width, and P is the integer number of half-wavelengths high the steps are at frequency f_A.

In the derivation of the above expressions, it has been assumed that the angle of incidence of the light is chosen larger than the angle giving peak response at the design frequency f_A. By choosing an angle giving 3dB less response at f_A, the overall 3dB bandwidth can be extended by a factor of $\sqrt{2}$.

From these equations, it can also be shown that for a given bandwidth $\Delta f = kf_A$, where k is the fractional bandwidth, of the array the maximum array length is given by:

$$L = 7.1 \; nv^2/k^2 f_A^2.$$

In order that the maximum 3dB frequency of the individual elements be larger than the upper 3dB frequency of the array, the parameter P is given by:

$$P = \begin{cases} 1 & k < 1.3 \\ 2 & k < 0.75 \\ 3 & k < 0.5 \end{cases}$$

Having specified P, then the number of steps is given by:

$$N = 6.6/Pk^2$$

The correct angle of incidence of the light, measured outside the medium, is:

$$\theta_{inc} = \lambda f/2v + 0.443 \; nv/Lf_A$$

The effective acoustic power density P_d is not the electrical power delivered to the transducer members **21**, because some power is lost by reflection due to electrical and mechanical impedance mismatch, by dissipation in the transducers, electrodes and bonding layers, and in the acoustooptic medium per se. These effects have been calculated and are considered in the overall design.

It is important that the illulminating beam have the proper diameter and position in the deflector aperture. The effect of acoustic attenuation in the deflection medium is to shift the center of the Gaussian laser beam toward the transducer members, thus decentering the output beam and enlarging the focused spot size, thereby reducing the resolution. Although this shifting of the beam has been recognized in the disclosures in the prior art, no suggestion nor teaching is included in the prior art for overcoming the defects. It should be realized that by deliberately shifting the illuminating beam toward the transducer array, the diffraction efficiency can be increased at the expense of resolution and, more important, by shifting the beam away from the transducer array, the resolution can be improved at the expense of efficiency. At one particular shift given by:

$$S_c/A = B(D/A)^2/69.5$$

where A is the aperture width, D is the diameter of the laser beam at $1/e^2$ irradiance level, and B is the acoustic attenuation across the aperture in decibels, the output beam is centered and the resolution is the same as for the case of a centered beam and no attenuation. It can be shown that an optimum design condition for most purposes is $D/A = 1$, so that the laser beam diameter is equal to the aperture width and the shift is:

$$(S - Sc)A = 0.15$$

For this choice of beam diameter and shift, the resolution is only slightly less than for the case of no attenuation (the spatial frequency at which the normalized modulation transfer function has dropped to $1/e$ is approximately 95% of its no-attenuation, no-shift value), and the effect of attenuation of the acoustic wave is $B/2$ decibels. Such a design can be used with attenuation to about 20dB across the aperture; beyond this the resolution begins to decline.

With reference again to FIGS. **2–5**, the deflector **14** is made preferably of a material such as lead molybdate. This material is currently the most important and useful of the materials developed in recent years for acoustooptic use in the visible light region. It has a high figure of merit $M_2 = 35.8 \times 10^{-18}$ cgs units, it has high transparency in the visible region, it has low acoustic attenuation (11 dB/cm-GHz^2), and it is not water-soluble. Although other materials having higher M_2 values are known, lead molybdate is the most satisfactory of the materials readily available in good optical quality for use with visible light. The block is cut and has the incident surface **25** and the exit surface **26** optically polished. The axes of block **20** per se can be oriented in a number of ways. If the longitudinal acoustic wave is propagated in the c-axis direction, as shown in FIG. **2**, then the optical wave is propagated perpendicular thereto. When the axes are such that the longitudinal acoustic wave is propagated in the a-axis direction, the optical wave is then propagated along the b-axis and polarized linearly along the a-axis, or is propagated along the c-axis and polarized along the b-axis. In the latter cases, the figure of merit is lower, $M_2 = 24 \times 10^{-18}$ cgs units. Although less efficient, this cut may be easier to fabricate because the crystal has a cleavage plane normal to the c-axis.

The steps **23** are cut into the end **24** of the block **20** which has the opposite end **27** and the upper and lower surfaces **28** and **29**, respectively, fine-ground. An acoustooptic absorber **30** of lead, aluminum, or epoxy loaded with tungsten powder to give an acoustic impedance approximately the same as that of the lead molybdate is bonded to the end **27**. The absorber **30** is utilized to prevent reflection of the acoustic waves set up within the block **20** by transducer members **21.** Aluminum or copper plates **31** and **32** are bonded with epoxy or other cement to the upper and lower surfaces **28** and **29**, respectively. These plates act as heat sinks and can also serve as a support for the deflector **14,** or in conjunction with plates **33** and **34,** as shown in FIG. **2** provide means for mounting the deflector **14** in the system, in an insulated manner, if required. In this latter case, plates **33** and **34** would be of an insulating material.

Each of the steps in the array **22** is provided with a transducer member **21** which is in the form of a rectangular plate and is preferably of lithium niobate, a well known transducer material that is readily available in good quality. This transducer material has a high electromechanical coupling coefficient (0.49) when cut as a 35° Y-cut, a fair acoustic impedance match to lead molybdate (34.8 and 26, respectively), and a low dielectric constant (39).

A transducer member **21** is bonded to each of the steps **23** in the array **22** with indium, designated by the numeral **35.** Indium bonding techniques are well known in the art. The use of indium or another metal bonding medium is necessary to achieve good impedance matching and high acoustic transmission. Even so, the high acoustic attenuation of indium would, if uncompensated, decrease the diffraction efficiency of the device at high frequencies unacceptably. In addition, the free air resonance frequency of a transducer is shifted to a lower value when it is bonded to a different medium. For these reasons, the transducer members **21** are cut thinner than required for resonance at the center frequency of the device **14.** By thus skewing the response of the transducer means **21** to higher frequencies by about 30%, their increased response at high frequency can be used to compensate for the increasing attenuation of the indium bond, thereby achieving a flatter overall response as related to deflection efficiency.

The numerical parameters of design for a deflector as described above are as follows:

Lead molybdate:

$M_2 = 36 \times 10^{-18}$ cgs units (acoustic propagation along c-axis)

$v = 3.75$ mm/μs

$n = 2.27$ at wavelength .64 μm

Transducer array:

$f_A = 175$ MHz

$L = 1.81$ cm

$N = 6$ transducer members

$P = 2$

$\Delta f = 125$ MHz

$P_d = 0.5$ w/cm^2

Transducer members: thickness 15.6 μm (resonant frequency **236 MHz**)

Bonds: Indium, 5 μm or less thick.

Optical efficiency: 10% or greater over full bandwidth, 25% at peak.

The matching circuit and connections between the transducers are shown in FIGS. **3–5.** A source of potential which will provide a predetermined frequency range can be an oscillator **36** including a transformer **37,** as shown schematically in FIG. **3,** and generally designated as an oscillator means **38.** The transducer members **21** are connected in series with oscillator means **38** by the connectors **40** arranged on alternate riser surfaces **39** as shown in FIG. **4.** The connectors **40** interconnect the indium layes **35** which bond the members **21** to their respective step **23.** Alternatively, the transducer members **21** can be connected by depositing thin-film conductive interconnecting layers **41** on the surfaces **28** and **29** of the block **20** rather than along the risers of each step, as shown in FIG. **5.** If the alternative method is used, the heat sink plates **31** and **32** are cut short so that they are clear of the layers **41** and, hence, cannot short circuit the layers **35.** The transducer members **21** are oppositely poled and radiate in phase, although connected in series. Hence, the electrical field direction alternates. The transformer **37** changes the impedance to match approximately that of the transducer members **21** to that of the oscillator means **38** or driving source and transmission lines. A part of the transformer **37** functions as a single coil which tunes out the static capacitance of the members **21** at their center frequency f_A.

With reference to FIG. **6,** the external electrical connections incorporating heat sinks are shown in conjunction with the acoustooptic deflector **14.** In this arrangement, a block **45** of insulating material is affixed adjacent the end surface **24** of the block **20** by suitable means secured to plates **29, 30** or **31, 32.** The insulating block **45** carries a number of rods **46** and **50,** each having fin-shaped ends **47** and extending ends **48** which engage a respective transducer member **21** when the block **45** is mounted relative to the end **24.** The rods can be of aluminum, copper or brass, of rectangular or circular cross section and blackened for good radiation. Such rods or fin-members can be placed on other surfaces of the deflector **14,** if used only as heat sinks, with the exception of the incident and exit surfaces **25,** 26.

As seen in FIGS. **3** and **6,** the rods **46** are connected to transformer **37** via lines **51** and **52.** The rods **50** also serve as connectors in that they are unitary in structure and provided with spaced ends **48*a*** which interconnect adjacent members **21.** Consequently, the transducer members **21** serve as electrical connectors to serially connect members **21** as well as heat sinks.

In operation, the laser **10** provides a small beam of monochromatic light which is imaged by the optical system including lenses **11, 12** and **13** as a narrow slit of light inside the deflector **14.** The beam is actually brought to focus at the mid-point or mid-plane of the deflector **14.** The source of potential or oscillator means **38** is connected through the transformer **37** to each of the transducer members **21** in a serial manner. At a predetermined acoustic frequency f, each transducer member propagates or radiates a wave of such frequency from the end **24** to the end **27.** The series of waves radiated by each transducer member **21** is shifted in phase. As a result, a composite wavefront is established by the array **22** of transducer members. The included angle formed by this composite wavefront and the incident light beam varies with the frequency f in such a manner as to maintain the Bragg condition over the frequency range Δf of the deflector. As the frequency changes through the full frequency range, the wavefront shifts and the included angle changes so that the emanating beam moves through an angle which is usable for recording or scanning. This angle will provide at least 1,500 beam positions as described above.

The device and system described hereinabove serves to deflect a laser beam of monochromatic light to at least 1,500 resolvable positions with retrace time of

13.3 μ sec. and provides a diffraction efficiency of at least 10% over the full frequency range or bandwidth. The time-bandwidth product is 1,665, but if used with a 10% flyback time in a linear scanning mode of operation, the effective resolution is reduced to 1,500 beam positions or spots. The device operates at a low power density, 0.5 w/cm^2. With good heat sink design, it can be operated at high power levels to achieve larger diffraction efficiency. It is believed that the overall design of utilizing decentered illumination with a beam of proper configuration to achieve an optimum trade-off of resolution and efficiency is unique with respect to the teachings of the prior art. Also, the use of high frequency transducer members which are capable of a frequency higher than the overall design frequency of the device compensates for attenuation in the various bonds that are required to unify the acoustooptical element per se.

The invention has been described in detail with particular reference to a preferred embodiment thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

We claim:

1. An acoustooptic light deflecting system having an efficiency greater than a minimum predetermined efficiency and operable with respect to the center frequency of a predetermined bandwidth, comprising:
- means for generating a beam of monochromatic light that is relatively narrow in width as compared to length and for directing the beam along a prescribed path;
- oscillator means for generating an electrical signal of a preselected frequency that is generally within the bandwidth;
- an acoustooptic medium responsive to a constant acoustical power and having center frequency that is offset with respect to the bandwidth center frequency, spaced, parallel incident and exit side surfaces and spaced, parallel ends, the medium being positioned in the prescribed path with the light beam intersecting the incident side surface at an angle to effect Bragg diffraction of the light beam and being displaced relative to the prescribed path in a direction to optimize the efficiency and resolution of the system;
- transducer means comprising a number of piezoelectric elements, each of generally rectilinear shape, bonded to one end in spaced-apart relation and extending generally in the direction of the path, and phasing means associated with each of the elements for radiating the latter in phase, the elements providing an array, having a resonance frequency that is offset relative to the bandwidth center frequency and being responsive to the selected frequency for generating a number of series of acoustic waves in the medium in accordance with the number of elements; and
- matching circuitry having an offset center frequency for electrically balancing and interconnecting the oscillator means and piezoelectric elements, whereby the incident beam is diffracted at a different angle by each series of waves to produce a diffracted light beam uniquely associated with the selected frequency, and whereby the offset of the center frequency of the medium, the array and the matching circuitry increases the efficiency over and above that greater than the minimum predetermined efficiency.

2. An acoustooptic light-deflecting system having an efficiency greater than a minimum predetermined efficiency and operable with respect to the center frequency of a predetermined bandwidth, comprising:
- means for generating a beam of monochromatic light that is relatively narrow in width as compared to length and for directing the beam along a prescribed path;
- oscillator means for generating an electrical signal of a preselected frequency that is generally within the bandwidth;
- an acoustooptic medium responsive to a constant acoustical power and having a center frequency that is offset with respect to the bandwidth center frequency, spaced, parallel side surfaces and at one end thereof having a series of steps extending generally in the direction of the path, the faces of the steps being generally parallel to each other and perpendicular to each of the respective side surfaces, the displacement of each face relative to the next face being a full wavelength as related to the bandwidth center frequency, the medium being positioned in the prescribed path with the light beam incident on one of the side surfaces at an angle to effect Bragg diffraction of the light beam and being displaced relative to the prescribed path in a direction to optimize the efficiency and resolution of the system;
- transducer means comprising a piezoelectric element of generally rectilinear shape bonded to the face of each step and in spaced relation to the step adjacent thereto, the elements providing an array, having a resonance frequency that is offset relative to the bandwidth center frequency and being responsive to the selected frequency for generating a number of series of acoustic waves in the medium in accordance with the number of elements; and
- matching circuitry having an offset center frequency for electrically balancing and interconnecting the oscillator means and piezoelectric elements, whereby the latter radiate in phase so that the incident beam is diffracted at a different angle by each series of waves to produce a diffracted light beam uniquely associated with the selected frequency, and whereby the offset of the center frequency of the medium, the array and the matching circuitry increases the efficiency over and above that greater than the minimum predetermined efficiency.

3. An acoustooptic light deflecting system in accordance with claim 2 including acoustic wave absorbing means fixed to the other end of the medium, the displacement of the medium being in a direction such that the incident light beam is effectively closer to the absorbing means for optimizing the resolution of the system.

4. An acoustooptic light-deflecting system in accordance with claim 2 wherein the displacement of the medium is in a direction such that the incident light beam is effectively closer to the series of steps for optimizing the efficiency of the system.

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